



SUPERSYMMETRY SEARCHES AT THE TEVATRON

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We report on the status and prospects of SUSY searches at CDF and D0 in Run II. Recent SUSY analyses from run I are also reported.

1 Introduction

For Run II, both CDF and D0 underwent significant improvement of the detectors to enhance their sensitivity to new physics. The detectors are commissioned and are taking data. The Tevatron is operating at a record center of mass energy of 1.96 TeV. Despite earlier difficulties, the luminosity situation is improving and both detectors have accumulated amounts of data comparable or higher than those available in Run I.

2 SUSY in Run II

In many cases, the discovery of SUSY particles or setting competitive limits requires large integrated luminosity and study of the low energy spectra of visible particles: in many scenarios SUSY particles undergo cascade decays resulting in low energy decay products. Exploring these scenarios requires sharp cuts between signal and background and a thorough understanding of soft backgrounds including well calibrated detector response at low transverse momentum. This is under way but will require more time and studies. Therefore, Run II results presented here consider the higher end of the energy spectrum.

2.1 Search for GMSB neutralino decay $\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$

Models with Gauge Mediated SUSY drew a lot of attention after the CDF $ee\gamma\cancel{E}_T$ candidate event¹. One of the model lines (referred to as Snowmass slopes) is GMSB with the lightest

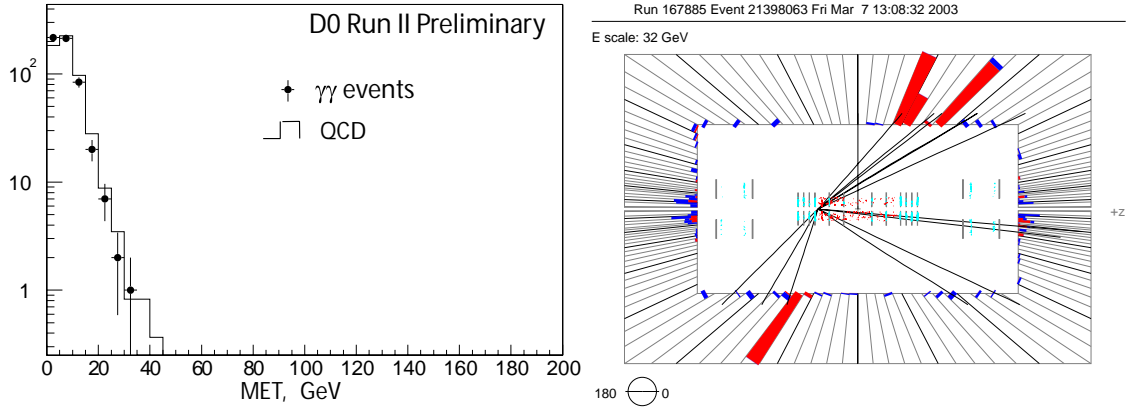


Figure 1: a) D0 GMSB search: \cancel{E}_T spectrum for $\gamma\gamma$ events compared to expected QCD backgrounds. b) D0 tri-lepton event: three electrons. This event passes all required cuts except for the \cancel{E}_T cut.

neutralino, $\tilde{\chi}_1^0$, as the NLSP. This slope is parametrized by the SUSY breaking scale parameter Λ , and the minimal GMSB parameters are as follows: the messenger mass scale $M = 2\Lambda$, number of messenger fields $N_5 = 1$, $\tan \beta = 15$ and the Higgsino mass parameter $\mu > 0$. Assuming the $\tilde{\chi}_1^0$ has not too long lifetime, one can search for the decays $\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$. The most promising processes are $p\bar{p} \rightarrow \tilde{\chi}_2^0 \tilde{\chi}_1^\pm$ and $p\bar{p} \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_1^\pm$ with the signature of two photons (one from each of the neutralinos) plus substantial missing energy, \cancel{E}_T .

The new D0 analysis requires two photons with $E_T > 20$ GeV in the central region of the detector ($|\eta| < 1.1$). The largest background, QCD, sharply falls as a function of missing transverse energy, \cancel{E}_T . The analysis looks into regions of $\cancel{E}_T > 25, 30$ and 35 GeV, and finds 9, 3 and 1 event, respectively. These are compared to the expectation of QCD backgrounds of 6.8 ± 1.0 , 3.4 ± 0.7 and 2.3 ± 0.6 events. A limit is set on the cross-section production or, equivalently, on the SUSY breaking scale Λ . The 95% C.L. result is $\Lambda > 51$ GeV, corresponding to $M(\tilde{\chi}_1^0)$ and $M(\tilde{\chi}_1^\pm)$ of 66 and 116 GeV/ c^2 . This limit already approaches similar Run I limits^{1,2} of $M(\tilde{\chi}_1^0) > 75$ (D0) and 65 GeV/ c^2 (CDF).

2.2 Low $\tan \beta$ SUSY: associated $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ production in MSSM

D0 has an analysis that searches for SUSY evidence in process $p\bar{p} \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow (\nu \tilde{l})(l\bar{l}) \rightarrow (\nu l \tilde{\chi}_1^0)(l\bar{\chi}_1^0)$, and the final states of $le\nu\tilde{\chi}_1^0\tilde{\chi}_1^0$ (di-electron) and $le\mu\nu\tilde{\chi}_1^0\tilde{\chi}_1^0$ ($e + \mu$) are studied. The analysis is based on a 42 pb⁻¹ data sample. The selection requires two tight electrons with $p_T > 10$ GeV/ c and at least one of them with $p_T > 15$ GeV/ c . In the $e + \mu$ sample, the electron is required to have $p_T > 20$ GeV/ c , and the muon must satisfy $p_T > 10$ GeV/ c . For the third lepton, a track of $p_T > 5$ GeV/ c , well separated from the two leading leptons, is required. For the di-electron sample, the analysis further requires an invariant mass of the di-electron system to be less than 70 GeV/ c^2 and $\cancel{E}_T > 15$ GeV to remove Z background. A cut on transverse mass of the leading electron and \cancel{E}_T , $M_T(e, \cancel{E}_T) > 15$ GeV/ c^2 further suppresses Drell-Yan and $W \rightarrow e\nu$. For the $e + \mu$ sample, a cut of $\cancel{E}_T > 20$ GeV and a requirement that the muon has either high $p_T > 20$ GeV or large $M_T(e, \cancel{E}_T) > 80$ GeV/ c^2 is applied. After all cuts, no events are observed in the di-electron data with an expectation of 0_{-0}^{+2} events from backgrounds. In the $e + \mu$ sample, two events are observed with an expectation of $1.5 \pm 1.5 \pm 0.1$. These results can be interpreted as an upper limits for the cross-section of $p\bar{p} \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_1^0$ production. Figure 1b) shows one of the tri-electron events before the \cancel{E}_T cut in di-electron data. Setting competitive limits will require greater integrated luminosity and possibly lowering the p_T thresholds as this analysis develops.

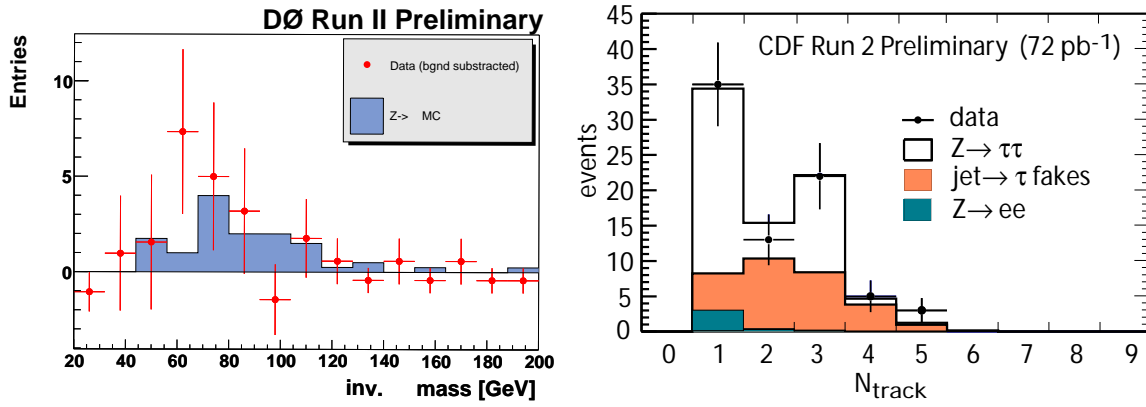


Figure 2: a) Mass spectrum of D0 τ candidates compared to Monte Carlo expectation; b) CDF τ candidate track multiplicity in the $Z \rightarrow \tau\tau$ analysis.

2.3 SUSY at high $\tan\beta$ and τ 's

There is a strong theoretical and experimental motivation for large $\tan\beta$. At $\tan\beta \geq 8$, the final leptons in $\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow \nu l \tilde{\chi}_1^0 l \tilde{\chi}_1^0$ are dominated by τ 's. This makes it very important to make full use of the detector and trigger capabilities to detect and reconstruct hadronically decaying τ 's and accept soft $\tau \rightarrow e/\mu$.

Both experiments have made a substantial effort towards better ability to use τ 's in Run II. The first step in this direction is the extraction of the $Z \rightarrow \tau\tau$ signal that serves as normalization and calibration for many future SUSY and Higgs analyses. For the D0 study of the $Z \rightarrow \tau\tau \rightarrow e\tau_h + \cancel{E}_T$ channel, the preselection starts with a requirement of a single isolated electron with $p_T > 15$ GeV/ c , and a loose 1-prong hadronic τ candidate with $p_T > 7$ GeV/ c . After applying additional cuts on the invariant mass $M(e, \cancel{E}_T) < 60$ GeV/ c^2 and $M(e, \tau) < 60$ GeV/ c^2 to suppress W +jet and $Z \rightarrow ee$ backgrounds, the events are separated into two types based on the presence of EM clusters in the τ candidate. After a requirement of spatial separation between the e and τ of $\Delta\phi < 2.88$, a neural networks analysis is employed to further discriminate real τ 's from fakes. Figure 2a) shows the invariant mass of the two τ 's corrected for \cancel{E}_T after background subtraction using like-sign data and corresponds to 42 pb⁻¹ integrated luminosity.

CDF has implemented unprescaled lepton (electron or muon with low $p_T > 8$ GeV) plus track ($p_T > 5$ GeV/ c , targets hadronic τ 's) triggers³ for Run II. These triggers can be used for any generic dilepton events including τ 's. The CDF $Z \rightarrow \tau\tau$ analysis uses data samples obtained with these triggers. Study of the $Z \rightarrow \tau\tau \rightarrow e\tau_h + \cancel{E}_T$ channel starts by requiring a good central electron of $p_T > 10$ GeV/ c and a hadronic τ candidate of $p_T > 20$ GeV/ c . QCD and W +jet backgrounds are suppressed using $|\vec{p}_T^e + \vec{\cancel{E}}_T| > 25$ GeV/ c and transverse mass of electron and \cancel{E}_T cut of $M_T(e, \cancel{E}_T) < 25$ GeV/ c^2 . After removal of Drell Yan and conversion electrons, the remaining background from jets is estimated using τ fake rates obtained from an unbiased jet sample. Figure 2b) shows the plot of τ candidate track multiplicity for $Z \rightarrow \tau\tau$ events in the electron channel compared to Monte Carlo prediction and background estimation.

3 Run I SUSY Advances

There are two recent Run I analyses we briefly describe in this report, both coming from CDF.

3.1 MSSM \tilde{t}_1 search

This CDF analysis is dedicated to a search of MSSM \tilde{t}_1 produced in $p\bar{p} \rightarrow \tilde{t}_1 \bar{\tilde{t}}_1$ process. The \tilde{t}_1 is assumed to further decay via $\tilde{t}_1 \rightarrow b\bar{l}\nu$ channel. The signature is two opposite charge leptons, two

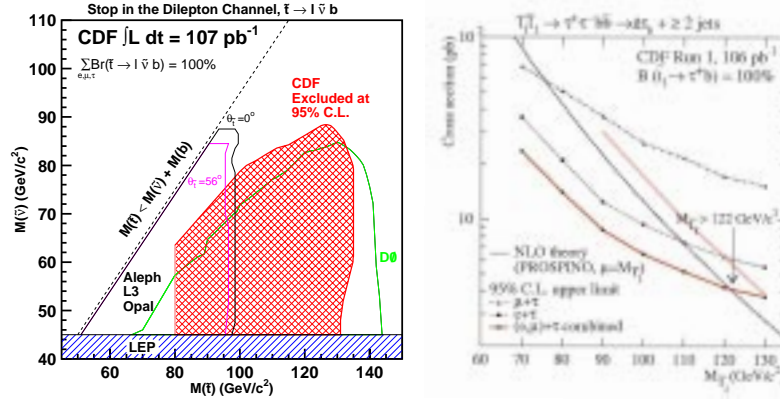


Figure 3: Preliminary CDF Run I limits on a) MSSM \tilde{t}_1 mass in $M(\tilde{t}_1)$ vs. $m_{\tilde{\nu}}$ plane; b) \tilde{t}_1 production for stop decaying via $R_p \tilde{t}_1 \rightarrow b\tau$ channel in the cross-section vs. $M(\tilde{t}_1)$ plane. The upper cross-section line shows the expectation for $\sqrt{s} = 2$ TeV.

hadronic jets and a substantial missing energy. The analysis requires one tight lepton candidate with $p_T > 10$ GeV/c, one loose lepton with $p_T > 6$ GeV/c and one jet with $E_T > 15$ GeV in the central region of the detector. Events are required to have large missing transverse energy $\cancel{E}_T > 30$ GeV. After all selection, no excess over the Standard Model expectations is found, and limits are calculated in the sneutrino versus stop mass plane, as shown in Fig. 3a), extending the LEP II limits to larger \tilde{t}_1 masses and increasing the sensitivity by a factor of 4 in comparison to previous search.

3.2 Search for R_p -violating $\tilde{t}_1 \rightarrow b\tau$ decay

CDF also searches for R_p -violating \tilde{t}_1 decay in the $\tilde{t}_1 \rightarrow b\tau$ channel via λ'_{333} or ϵ_3 couplings in the process $p\bar{p} \rightarrow \tilde{t}_1 \tilde{t}_1^* \rightarrow (b\nu_l \bar{\nu}_\tau)(\bar{b}\tau_h)$. This analysis searches for two τ 's, one decaying leptonically and the other decaying hadronically. Two additional jets are required in the same event. The selection requires a lepton (e or μ) with $p_T^l > 10$ GeV/c accompanied by a hadronically decaying τ candidate with $p_T^\tau > 15$ GeV/c in the central region. A total of 642 events pass the above requirements, 16 of them have two or more extra jets of $E_T > 15$ GeV/c and $|\eta| < 2.4$.

$Z \rightarrow \tau\tau$, $t\bar{t}$ and diboson backgrounds are estimated by using Monte Carlo, while QCD backgrounds are estimated using like-sign events. After further applying event topology cuts $M_T(l, \cancel{E}_T) < 35$ GeV/c² and $\sum p_T \equiv p_T^l + p_T^\tau + \cancel{E}_T > 75$ GeV/c, no events are observed with an expected $3.2^{+1.4}_{-0.3}$ background events. Limits are set on \tilde{t}_1 production and decay versus the \tilde{t}_1 mass plane as shown in Fig.3b). At 95% C.L. a lower limit of $M(\tilde{t}_1) > 122$ GeV/c² is set assuming 100% branching ratio.

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